Establishing Volume Reduction Goals and Reducing Stormwater Runoff Using Low Impact Development to Improve Coastal Water Quality

by

Shannon Fouts

Dr. Mike Orbach, Advisor

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Abstract

Despite the Clean Water Act (CWA), passed by Congress in 1972, coastal water quality has continued to decline. The primary reason is the Act's failure to adequately deal with stormwater runoff, the leading source of water pollution in coastal areas. Coastal development causes the velocity and volume of rainwater running off the land to increase, picking up pollutants in the process. Traditional stormwater systems convey that runoff directly into watersheds and coastal waters. Alternatives to the tradition stormwater systems exist that prevent runoff, instead of conveying it off the land as fast as possible. Low impact development (LID) is one option that uses a variety of techniques to mimic the lands natural hydrology by holding rainwater on the land and allowing it to infiltrate the soil. LID incorporate fairly simple measures, such as disconnecting downspouts from impervious surfaces, using rain barrels to capture runoff, and installing rain gardens, to reduce the runoff from development.

Reducing stormwater runoff can be an effective way to improve water quality in areas where waters are not meeting their designated uses established under the CWA. This can be done by bringing runoff levels back to historically acceptable volumes. This analysis uses the methods in the NC Coastal Federation's Watershed Restoration Planning Guidebook to establish a stormwater runoff volume reduction goal by calculating the increase in runoff between 2004 and 2013 in Beaufort, NC. The study demonstrates the ease of setting reduction goals using the NCCF guidebook methods. It then presents various LID techniques as a cost effective approach to meet the reduction target.

The results for the 9-year period show a 7% increase in stormwater runoff volumes. The estimated increase in runoff volume was 423.876 acre-feet. The runoff rate went from 54% to 61%. This correlates closely with the increase seen in impervious surfaces in the study area. Impervious cover went from 29% in 2004, up to 37% in 2013, an 8% increase.

Table of Contents

Introduction

Clean water is one of the most valuable resources on our planet. Without it there would be no life on Earth. Humans can only go about 2 to 3 days without water, but can potentially go 30 to 40 days without food. We need water for the agriculture and livestock that feed us. Clean water is also necessary for the fisheries that provide 3 billion people with almost 20% of their dietary intake of animal protein and another 4.3 billion with nearly 15% of this protein. In developing countries, such as Bangladesh, Cambodia, Sri Lanka, Indonesia, Ghana, and Sierra Leone, it is even more vital, providing 50% or more of the animal protein in their diet. (FAO, 2012) In addition, the phytoplankton living in the world's oceans produce over half the oxygen that we all breath (WWF).

The importance of protecting this precision resource was recognized in the U.S. with the enactment of the Clean Water Act in 1972. Despite the value of water, a review of academic literature clearly shows an increase in water quality issues globally. One prevalent issue is the spreading cases of eutrophication occurring in coastal waters. (Boesch, 2002) Eighty percent of the nutrient loads and pollutants that are the source of these eutrophic conditions come from land via runoff (NOAA, 2014).

Stormwater Contributions to Water Pollution in the US

Stormwater runoff has become the primary cause of coastal water pollution in the United States (EPA_1, 2012). Increasing amounts of development and changing land use from natural land cover to alternative uses such as agriculture and forestry are responsible. Removing native vegetation and increasing impervious surfaces reduce the ability of rainwater to infiltrate the soil. The result is an increase of stormwater runoff that carries pollutants into the surrounding watershed. As the volumes of runoff increase, so do the amounts of pollutants that are picked up. In addition to the fertilizers, pesticides, pet waste, and numerous other pollutants that are picked up by the runoff, soil and the heavy metals associated with it are also carried off. This runoff then flows into surrounding waterbodies or stormwater drains that carry it directly into streams, rivers, lakes, and coastal waters. (EPA, 2003)

Everyone contributes to stormwater runoff in one-way or another. Residents contribute when they fertilize their yards, wash their cars on impervious surfaces, or fail to clean up after their pets, which are a major source of bacterial pollutants in coastal waters (EPA, 2003). Agriculture is one of North Carolina's biggest contributors to runoff pollutants due to excess use of pesticides and fertilizers or animal waste. Golf courses are another big contributor to excess nutrient loads in runoff because of the copious amounts of fertilizer used on them. (Shutak, 2013) Construction and forestry also contribute to runoff issues due to erosion resulting from removal of the native land cover. Commercial and residential developments increase impervious cover, which reduces the ability of rainwater to infiltrate, increasing the volume of storm runoff. (EPA, 2003)

Impacts on Coastal Habitats

The pollution carried into coastal waters has a number of serious impacts on coastal ecosystems. Sedimentation can destroy aquatic habitats and clouds the water, making it much harder for aquatic plants to grow. This can cause declines in aquatic vegetation, such as sea grass beds, which are an important source of food, habitat, and dissolved oxygen for fish and other species. Bacteria from animal waste and other terrestrial sources can cause degraded water quality, making some activities such as shellfishing or swimming unsafe due to risks of illness. These polluted areas end up being closed to human use, sometimes permanently. The excess nutrients from agriculture and other sources can cause algae blooms and red tides or other toxic events. Large algae blooms can cause low dissolved oxygen (DO) episodes as they die, sink to the bottom, and decay, since bacteria consume oxygen as they break down the dead organic matter. Low DO can reduce species diversity and result in species mortality, such as mass fish kills. Chemical pollutants including insecticides, pesticides, solvents, and oil can be toxic to aquatic life. In addition, once the toxins build up in fish or shellfish, animals or people that eat them can get sick or die.

Impacts on Human Health

Stormwater runoff also transports heavy metals along with sediment. Copper, zinc, and lead that wash off of roads, parking lots, and roofs in significant concentrations can be toxic to humans. In addition, insecticides, which can be found in fish at concentrations high enough to be harmful, are endocrine disruptors and carcinogenic to humans. Drinking water that becomes contaminated with protozoan oocysts, viruses, and bacteria from stormwater runoff can cause acute illnesses. A 1995 study that sampled filtered drinking water treated with chlorine found that 13% still contained Cryptosporidium oocysts. It is estimated that 99 million people in the United States have acute gastrointestinal illnesses every year, up to 40% of which may be due to contaminated drinking water. Since 1948, over half of the known waterborne illness outbreaks have occurred after extreme rainfalls.

(Gaffield *et al*. 2003) These illnesses add up to billions of dollars a year in medical costs and lost productivity (Garthright *et al*. 1988).

Impacts on Water Quality

The impacts from stormwater runoff on water quality are well documented. In 2005, the EPA reported that 28% of U.S. coastal waters were unsuitable for aquatic life and another 22% were unsuitable for human use (NOAA, 2010). In 2006, a report by NOAA stated there were 30,000 closures and advisories, 73 extended closures lasting 7 to 13 weeks, and 69 permanent closures for U.S. beaches. Of the closures and advisories with know causes, 40% were attributed to runoff. The report further indicated that by 1995, 3.5 billion acres of shellfish beds had been closed, accounting for 1 in 7 acres in the nation. Ninety-five percent of these closures were attribute to runoff in 14 of the 21 coastal states. (NOAA, 2007)

Techniques to Reduce Runoff

The North Carolina Coastal Federation (NCCF) is one environmental groups that has recognized the impact stormwater runoff is having on coastal water quality and begun working with stakeholders to find solutions to reduce runoff and restore water quality. By working with farmers, developers, city or community officials, and other stakeholders, the NCCF is in a better position to help develop improved management practices. For farmers this can include more precise application of fertilizers using GPS in their tractors to reduce nutrient runoff or restoration of wetlands and buffers around croplands to filter runoff (UIE, 2013). For developers and city officials it can involve showing them Low Impact Development (LID) alternatives that help reduce runoff and provide a more cost effective option for development.

To improve coastal water quality that is degraded by stormwater runoff, a baseline for historical runoff in the area of concern needs to be established. This can be done using GIS with data for hydrologic soil groups, aerial photography, parcel data, and parameters for the one-year 24-hour storm in the delineated area. The baseline, ideally, should be established based on runoff levels for 1975, when the CWA established designated uses for surface waters. If data for 1975 are not available, then data as far back as possible should be used to establish historic runoff volumes. The aerial photography available through the Carteret County Planning Office used in this analysis, for example, only went back to 2004. Next use the most recent data available to estimate the current levels of stormwater runoff.

The difference between the current and historic runoff volumes is established as the volume reduction goal. (NCCF, 2013)

Cities and communities can use the NCCF's online Watershed Restoration Planning Guidebook, or similar resources provided by their local government, to create a watershed management plan. The NCCF's guidebook maps out the runoff reduction goals and the steps that will be implemented to achieve these goals. Including local stakeholders and designing education and outreach programs are also part of this watershed management plan. The methodology in the guidebook additionally incorporates the nine elements of a watershed management plan required by the EPA, in their EPA Handbook for Developing Watershed Plans, to qualify for the 319 grant funding. By including these nine elements, there is a better chance that the management plan can serve in lieu of a total maximum daily load (TMDL). Since TMDLs are much more time intensive and costly to produce and implement, this can be a considerable benefit for communities. (NCCF, 2013)

LID techniques are used to achieve the reduction goals set out in the watershed management plan. These techniques are flexible, easy to implement, and cost less than other reduction alternatives, making LID an ideal means to address runoff. LID minimizes the impact of development by holding rainwater on the land and allowing it to infiltrate slowly, mimicking the lands natural hydrology. Doing this helps to preserve the much lower natural runoff rates. LID incorporates five basic strategies:

- Conserve natural resources (wetlands, water, trees, & special areas), drainage patterns, topography, and soil, when feasible
- Minimize impacts from development & construction on natural hydrologic cycles by saving existing flora and reducing impervious surfaces, clearing, grading, & pipes
- Enhance water infiltration by slowing down runoff & increasing contact time with the landscape through saving natural drainage patterns and maintaining sheet flow using vegetative swales, lengthened flow paths, & flattened slopes
- Establish spaces for local storage and treatment of rainwater by using small-scale practices that allow on site collection, retention, storage, infiltration, and filtering
- Foster capacity for maintenance: Cultivate dependable, long-term maintenance programs that have well-defined enforceable guidelines and educate residents, management companies, and local government staff on the operation & upkeep of all procedures and water quality protection

There are a variety of LID alternatives that can be used to achieve the established runoff reduction objectives. There are versatile options that can be used for both new and existing developments. Which methods are chosen will depend on a number of site specific-factors, including soil and land cover type, and land use. (NCSU, 2009)

Existing developments - residential, commercial, industrial, civic, or municipal - can be retrofitted with a number of LID options. Downspout diverters can be used to direct rainwater off impervious surfaces into gardens or other vegetated areas. Rain barrels or cisterns can be used to catch rainwater and save it for watering lawns and gardens. Rain gardens or backyard wetlands can be installed, incorporating native plants, to hold rainwater and allow infiltration and uptake by plants. These and other alternatives to disconnect impervious surfaces (curb cuts, vegetated swales, pervious pavement, etc.) can be incorporated into existing urban development (parking lots, public right of ways, green spaces, etc.) as part of Capital Improvement Projects or the routine maintenance and repairs done on urban infrastructure. (NCSU, 2009)

In fact, the successful use of LID site design techniques can significantly decrease the price of supplying stormwater management. These savings are a result of reduced or eliminated stormwater management ponds and reducing the amount of inlet structures, gutters, street paving, curbs, and the extent of grading and clearing required during construction. Depending on the stormwater and site development design, development type, and site constraints, the construction and maintenance expenditures can be reduced 25% to 30% compared to conventional methods. (NCSU, 2009)

When LID is incorporated into the plans for new development it can result in additional value and cost savings over conventional development. According to an evaluation done by the EPA, LID practices benefit communities economically and environmentally. The reduced costs for site grading and preparation, paving, landscaping, and stormwater infrastructure (ponds, gutters, curbs, pipes, and inlet structures) resulted in a capital cost savings of 15% to 80%. Environmental goods and services provide additional benefits including enhanced aesthetics, increased recreational prospects, boosted property values related to the desirability of lots in close proximity to open spaces, more units built, greater marketing potential, and quicker sales. (NCSU, 2009)

LID provides a number of other benefits. Water quality is improved because the amount of stormwater runoff that reaches coastal waters and watersheds is reduced. The number of flood events, caused when large volumes of stormwater enter waterway too quickly, will decrease. Aquatic habitats, degraded when rapidly moving storm runoff erodes stream banks and scours stream channels, can be restored to their natural function and vitality. Ground water recharge is improved because water is allowed to infiltrate soil and seep down into the water table, instead of quickly running off the land. Moreover, LID enhances neighborhood beauty, making communities more attractive, sustainable, and wildlife friendly, which in turn can increase property values. (EPA$_5$, 2012)

Stormwater Infrastructure in the Town of Beaufort

The purpose of this analysis is to illustrate both the ease of the NCCF's methods for establishing runoff reduction goals and the cost effectiveness of implementing LID measures to meet them. To demonstrate the procedures in the NCCF's watershed guidebook, the Town of Beaufort was selected as the boundary area. Beaufort was chosen for this analysis for several reasons. First, it is a smaller and more manageable area than an entire watershed, which still provides a good representation of a typical coastal community for the purposes of this analysis. Second, being located on a peninsula, Beaufort is bordered by the North River, Newport River, and Taylors Creek. The salt marshes and estuarine waters from all three constitute the majority of the town's Areas of Environmental Concern (AECs), which nearly surround it. Third, Beaufort currently uses an outdated storm drain system that empties the majority of the stormwater runoff directly into Taylors Creek. This system needs to be updated and implementation of LID techniques to reduce runoff could potential save the city money over expanding their traditional stormwater infrastructure. (The Wooten Co., 2006) Fourth, various LID alternatives exist that could be used in Beaufort to meet the established reduction goals, alternatives that will be presented as part of this evaluation.

The stormwater drainage facilities in Beaufort that existed in 2006 were made up of a system of pipes, catch basins, swales, and drainage ditches. The wastewater treatment plant was built in 1969, was upgraded once in 1986, and was so old that repairs often required special parts that had to be custom made. The 2006 Beaufort CAMA Land Use Plan included plans to make improvements to the stormwater and sewer system in an effort to protect water quality. (The Wooten Co., 2006) These intended renovations stemmed from Beaufort's inclusion on the state's top 25 worst sewer systems list. Due to growing problems with sewer spills into the sensitive waters surrounding the Town, the state had threatened a moratorium on new sewer hookups. (Gannon, 2006) In order to avoid this ban, as well as related fines and penalties, Beaufort agreed to make $18 million in repairs to the pipes and build a new wastewater treatment plant. Part of the rehabilitation to the system included preventing rainwater from spilling into the sewer system, causing an unnecessary increase in demand on the wastewater treatment plant. (Pippin, 2008)

Materials & Methods

In this section I will calculate the volume of stormwater runoff for two different years in the Town of Beaufort. The most current year aerial photography was available through the Carteret County Planning Office was 2013 and the oldest was for 2004, so these were the years used in this analysis. The first part of the analysis is done using GIS to determine the land uses for each year and estimate the amount of impervious surface. After completing the GIS portion, the tables are exported and the totals are input into the NCCF Runoff Calculation Tool. This tool then tabulates the volume of runoff for each of the years. I took the difference between the runoff volumes for 2004 and 2013, the increase in runoff volume, and set that amount as the reduction goal for the Town.

Establish Stormwater Volume Reduction Goals

Data Collection

The first step for establishing volume reduction goals is to collect data. The data needed for the runoff estimates includes the defined Beaufort city boundaries, city parcel and right-of-way (ROW) data, hydrologic soil groups (HSG), current and historic aerial photography and the 1-year 24-hour storm parameters for the Beaufort area. The HSG data were downloaded from the National Resource Conservation Service Web Soil Survey website and a map showing the HSGs in Beaufort can be found in Appendix A. The 1-year 24-hour storm parameters, which represent the amount of rain received in a 24-hour period for a storm occurring an average of once a year, can be found on NOAA's Precipitation Frequency Data Server (Figure 1). The rest of the data were collected from the GIS Manager, Allen Willis, in the Carteret Country Tax Office. For the land use comparison, aerial photography for 2004 and 2013 were used. These aerial photos represent the oldest and newest data available for Beaufort for the purposes of this runoff estimate. These data, except the aerial photography, were obtained as shapefiles for use in ArcMap (ESRI). The aerial photography for 2004 was received as a series of .tif files for the Beaufort area and the 2013 aerial photos as a single .sid file for all of Carteret County.

Figure 1: NOAA Storm Parameters Table

NOAA Atlas 14, Volume 2, Version 3
Location name: Morehead City, North Carolina, US*
Coordinates: 34.7333, -76.7333
Elevation: 8 ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.479** (0.443-0.518)	**0.565** (0.521-0.610)	**0.660** (0.607-0.712)	**0.737** (0.678-0.795)	**0.833** (0.761-0.896)	**0.907** (0.827-0.978)	**0.981** (0.890-1.06)	**1.05** (0.950-1.14)	**1.15** (1.03-1.24)	**1.23** (1.09-1.33)
10-min	**0.765** (0.708-0.827)	**0.903** (0.833-0.976)	**1.06** (0.972-1.14)	**1.18** (1.08-1.27)	**1.33** (1.21-1.43)	**1.44** (1.32-1.56)	**1.56** (1.42-1.68)	**1.67** (1.50-1.80)	**1.82** (1.63-1.97)	**1.94** (1.72-2.10)
15-min	**0.956** (0.885-1.03)	**1.14** (1.05-1.23)	**1.34** (1.23-1.44)	**1.49** (1.37-1.61)	**1.68** (1.54-1.81)	**1.83** (1.67-1.97)	**1.97** (1.79-2.12)	**2.11** (1.90-2.27)	**2.29** (2.05-2.48)	**2.43** (2.15-2.63)
30-min	**1.31** (1.21-1.42)	**1.57** (1.45-1.70)	**1.90** (1.75-2.05)	**2.16** (1.99-2.33)	**2.49** (2.28-2.68)	**2.75** (2.51-2.97)	**3.02** (2.74-3.25)	**3.28** (2.96-3.54)	**3.64** (3.26-3.94)	**3.93** (3.49-4.26)
60-min	**1.64** (1.51-1.77)	**1.97** (1.81-2.13)	**2.44** (2.24-2.63)	**2.81** (2.59-3.04)	**3.32** (3.03-3.57)	**3.73** (3.40-4.02)	**4.16** (3.77-4.48)	**4.61** (4.15-4.97)	**5.23** (4.67-5.65)	**5.74** (5.09-6.23)
2-hr	**2.04** (1.87-2.21)	**2.48** (2.29-2.71)	**3.15** (2.90-3.42)	**3.71** (3.40-4.02)	**4.49** (4.09-4.85)	**5.15** (4.66-5.57)	**5.84** (5.28-6.32)	**6.59** (5.91-7.13)	**7.65** (6.78-8.31)	**8.54** (7.51-9.28)
3-hr	**2.21** (2.02-2.42)	**2.69** (2.46-2.95)	**3.42** (3.12-3.76)	**4.06** (3.68-4.45)	**4.97** (4.49-5.43)	**5.77** (5.18-6.30)	**6.62** (5.91-7.22)	**7.55** (6.68-8.24)	**8.91** (7.79-9.77)	**10.1** (8.73-11.1)
6-hr	**2.67** (2.40-3.00)	**3.24** (2.92-3.64)	**4.14** (3.71-4.65)	**4.92** (4.41-5.53)	**6.05** (5.38-6.77)	**7.03** (6.21-7.86)	**8.10** (7.10-9.04)	**9.27** (8.07-10.3)	**11.0** (9.42-12.3)	**12.5** (10.6-14.0)
12-hr	**3.17** (2.84-3.61)	**3.86** (3.46-4.39)	**4.95** (4.41-5.63)	**5.92** (5.26-6.74)	**7.32** (6.44-8.31)	**8.56** (7.47-9.68)	**9.92** (8.57-11.2)	**11.4** (9.79-12.9)	**13.7** (11.5-15.4)	**15.7** (13.0-17.6)
24-hr	**3.66** (3.40-3.99)	**4.46** (4.14-4.86)	**5.77** (5.35-6.28)	**6.87** (6.34-7.47)	**8.49** (7.78-9.23)	**9.89** (8.98-10.7)	**11.4** (10.3-12.4)	**13.1** (11.7-14.3)	**15.7** (13.6-17.1)	**17.8** (15.3-19.6)

Import & Organize Data

The steps for establishing volume reduction goals using ArcMap utilized in this analysis are outlined in Chapter 6 of the NCCF Watershed Restoration Planning Guidebook. The first task in the process was to estimate the amount of impervious surface, open space, ROW, and water or wetland area in acres. To do this a geodatabase was created in ArcMap and feature datasets for Base Data (soil, parcel, and city boundary), ROW, and Land Use were set up in the geodatabase. The aerial photography was not kept in the geodatabase. Once all the data were gathered they were imported into the geodatabase. All data were defined and projected as needed to NAD 1983 StatePlane North Carolina FIPS 3200 (Feet).

After making sure all the files were defined and projected correctly the Beaufort city boundary shapefile was used to define the limits for the area of interest for the runoff estimate. The "Clip" tool was used to clip each of the shapefiles (soil, parcel, and ROW) to the boundary area. The aerial photography did not need to be clipped.

Create a Current ROW Template

In the NCCF Watershed Restoration Planning Guidebook steps are outlined for creating a ROW template, however, the ROW shapefile for Carteret County was already provided so it was not necessary to generate one. The ROW shapefile only needed to be clipped to the city boundaries and compared to the 2013 aerial photo to verify that the polygon template and aerial photo agree. Since the ROW shapefile and most current aerial photo were both from 2013 they matched and no editing was required.

Establish Current Land Use

To determine the current land use, a new feature class was created in the Land Use feature dataset and named “Land_Use_Current”. The Land_Use_Current was added to a new map and a field named “Impervious” and another named “Land_Use” were added to its attribute table. After beginning an edit session, polygons were drawn around areas of homogenous land use. For each polygon a land use type was assigned to the “Land_Use” field in the attribute table using the Land Use Codes (R, C, W, or O) listed in Table 1. After zooming in to each polygon area and inspecting the amount of area covered by impervious surfaces such as rooftops and driveways, the amount of impervious surface was estimated in increments of 5% and the value entered into the “Impervious” field in the attribute table

Table 1: Land Use Classifications

Land Use Code	Land Use Type
R	Residential
C	Commercial
W	Water and Marsh
O	Forested or Open Space

After completing all the polygons and saving the edits, the edit session ended. The ROW template was then used in the “Erase” tool to remove the ROW polygon area from the “Land_Use_Current” file.

Create a Historic ROW Template

A copy of the current year ROW template was made and renamed “ROW04_project”. In a new map the aerial photos for 2004 were added along with the “ROW_2004_clip” file. An edit session was started and the ROW template was compared to the aerial photo. Any ROWs that did not exist in 2004 were deleted. When the ROW matched the 2004 photos the edits were saved and the edit session ended.

Establish Historic Land Use

A copy of the "Land_Use_Current" dataset was made, renamed "Land_Use_2004", and added to the map. An edit session was started for this file and each polygon was compared to the 2004 aerial photos. Polygons were amended as needed to match the 2004 land use. The attribute table "Impervious" values and "Land_Use" classifications were updated accordingly. Once all the necessary changes were complete the edits were saved and the session ended. The "Erase" tool was then used to remove the "ROW04_project" from the "Land_Use_2004" dataset.

Intersect Soil Type With Current Land Use

Before combining the land use shapefiles with the HSG shapefile the soil classifications needed to be edited. In an edit session, each HSG classification in the attribute table consisting of a combination HSG (AD, BD, CD) was reassigned to the lower classification. If the initial HSG classification was AD it would become D, for example. The reclassified HSGs for Beaufort can be seen in the map in Appendix C. After saving the edits and stopping the edit session, the "Intersect" tool was used to combine the "Land_Use_Current" and "Land_Use_2004" datasets with the HSG file. The output files were named "Land_Use_Current_Soil" and "Land_Use_2004_Soil". The current land use (2013) by soil type is illustrated in the map in Appendix B.

Export Attribute Tables

A field named "Area_acres" was added to the attribute tables for each of the land use datasets ("Land_Use_Current_Soil" and "Land_Use_2004_Soil") and ROW datasets ("ROW_13clip" and "ROW04_project"). Using the "Calculate Geometry" option from the right click drop down menu, the area in "Acres US [ac]" was calculated for this field in each dataset. The tables were each exported using the same name as the dataset using the dBASE Table format.

Table Calculations

After opening the "Land_Use_Current" and "Land_Use_2004" tables in excel, they were sorted by land use and then hydrologic soil type. Two columns were added to the spreadsheet, "Impervious area acres" and "Open space acres". The "Impervious area acres" were calculated first for all the commercial, residential, and open space records by multiplying the "Area_acres" by the value in the "Impervious" column and then dividing by 100. The "Open space acres" were then calculated for each record by taking the difference between the "Area_acres" and the "Impervious area acres". The "Impervious area acres" and “Open space acres” were then summed for each land and soil type. The “Area_acres” were then also summed for the water/marsh land use type.

Calculating Current & Historic Stormwater Runoff Levels

The total runoff for the historic baseline year and current year were calculated using the Runoff Calculation Tool (excel spreadsheet) provided by the NCCF. The spreadsheet provides space to input information for multiple years, permitting current and historic runoff as well as intermediate years to be calculated. The rainfall depth for the 1-year 24-hour storm was entered in the yellow cell next to “Precipitation”. The summarized areas for commercial and residential land use and soil type were input under the corresponding yellow cells in the “Land Use Summary Table” (Figure 2). The table only provides space for residential or commercial totals so the open space land use totals can be added under either of these alternatives. The summarized acres for the open space land use for both years in this analysis were included in the residential categories on the table. The ROW and water/marsh “Area_acres” totals were also added to their corresponding yellow cells. A “Land Use Summary Table” was filled out for each year, 2013 and 2004. When the totals are entered into the “Land Use Summary Table” the Runoff Calculation Tool does the calculations automatically and displays the total stormwater runoff in the blue cell next to “Runoff Volume (acre-feet)”.

Figure 2: Land Use Summary Table 2013

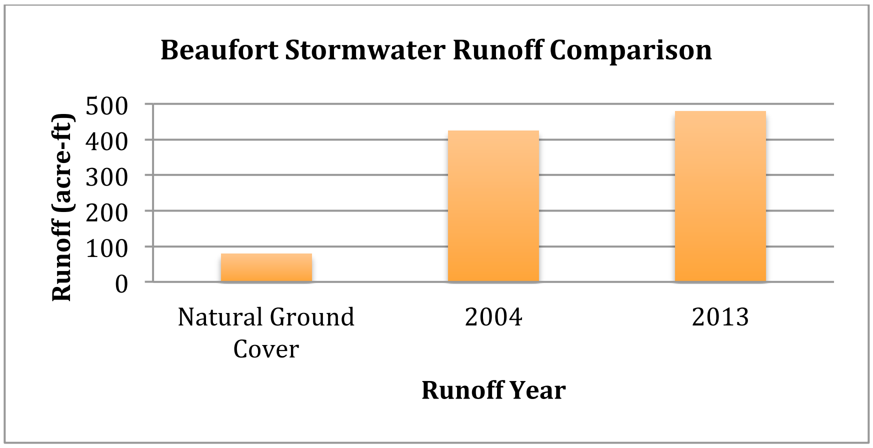
2013	**Land Use Summary Table**				
Soil Group	Residential Open Space	Residential Impervious	Commercial Open Space	Commercial Impervious	Total Area
A	17.55	18.81	3.95	12.85	53.16
B	101.71	47.35	22.75	42.47	214.28
C	224.13	58.53	58.59	78.65	419.90
D	945.16	175.42	161.81	150.49	1432.88
W					0.00

Water / marsh	102.75
ROW	360.56
Total Area	2583.54
Precipitation	3.66
Runoff Volume (acre-feet)	478.7890143

Results

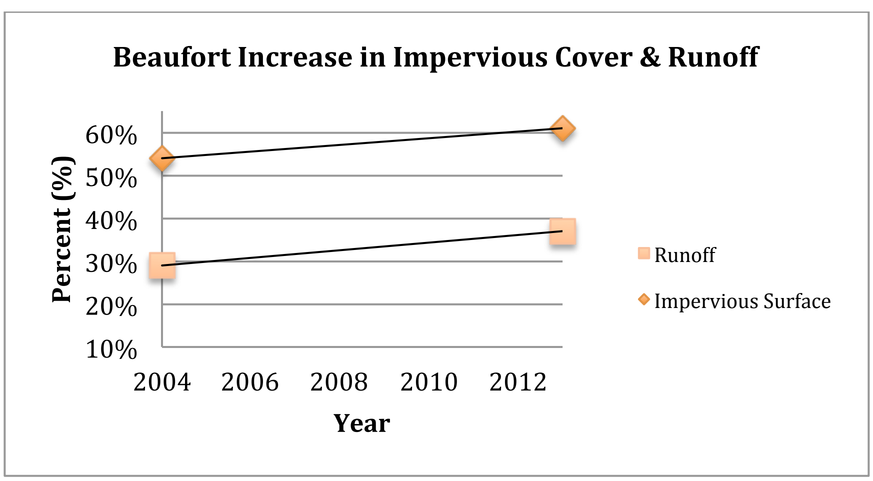
The estimated level of stormwater runoff in 2004 is estimated to be 423.876 acre-ft. and 2013 is 478.789 acre-ft. The 2013 runoff volume represents a 13% increase over the 2004 amount. In 2013 for the 1-year 24-hour storm an average of 787.9797 acre-ft. of water fell. The 478.789 acre-ft. of stormwater runoff represent a runoff rate of 61% for 2013. In 2004 the runoff rate was 54%. Over the 9-year period stormwater runoff increased 7%. Natural ground cover is estimated to have a 10% runoff rate on average (Arnold, Jr. & Gibbons, 1996). The runoff levels for 2004 and 2013 are compared to the amount of runoff that would be seen in Beaufort at the 10% runoff level that would exist prior to development in Figure 3.

Figure 3: Comparison of Beaufort Runoff to Natural Levels



Based on the 10% runoff estimate, the 2004 runoff rate is 44% higher and 2013 is 51% greater than the undeveloped land. In 2004 there was approximately 29% impervious cover in Beaufort. In 2013 this increased to 37% impervious area, representing an 8% increase in impervious surface. The results show the expected correlation between increasing impervious cover and higher runoff volumes (Figure 4).

Figure 4: Beaufort Impervious Cover & Runoff By Year

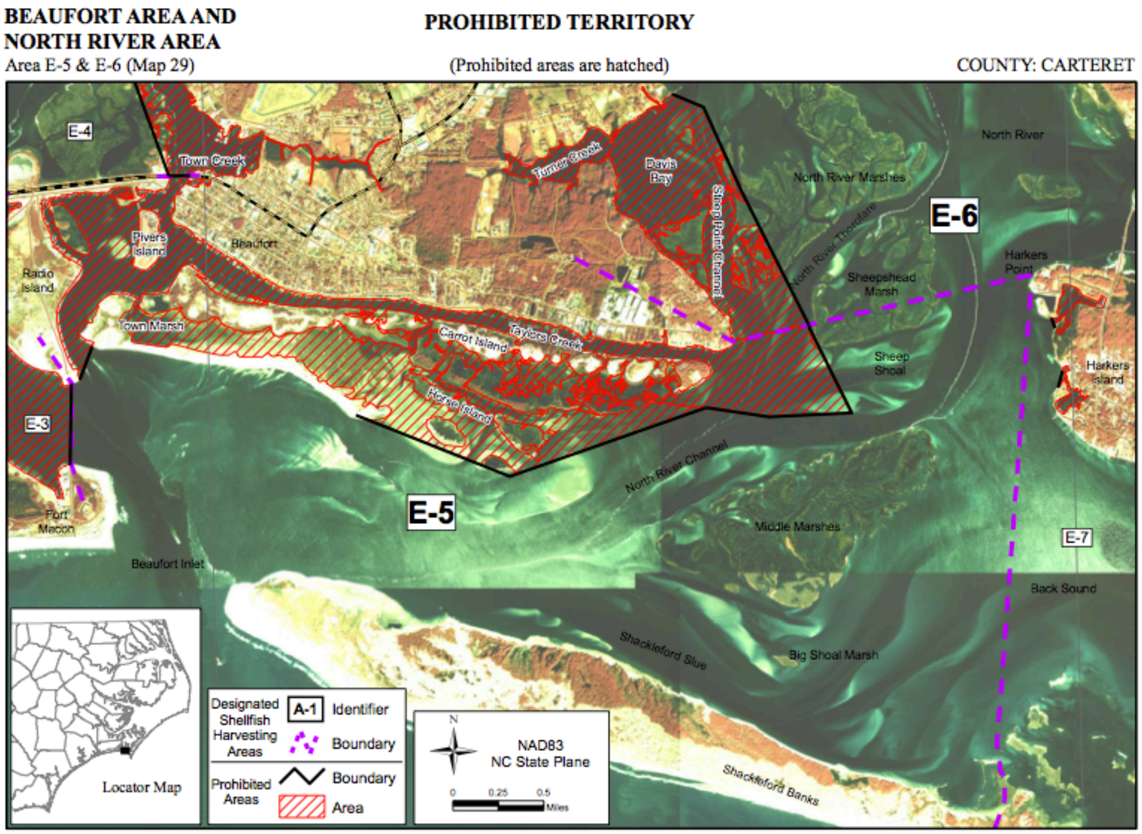


Discussion

Beaufort falls within the subbasins for the Newport and North Rivers. Both rivers are tributaries of the White Oak River, in the White Oak River Basin. Beaufort makes up about .22% of the area in the White Oak River Basin, while the Town's population comprised 2.58% of the total population in the basin back in 2001. In 2006, urban development made up 4% of the Newport River subbasin and merely 1% of the White Oak River subbasins. In the Newport River subbasin the bulk of the development lies along the coast and is comprised of Beaufort, Morehead City, Atlantic Beach, and Bogue Banks. The most densely developed areas in the North River subbasin are Atlantic, at the northern extent, and Harkers Island, at the southern edge. Open Grounds Farm, which contains agricultural land, makes up a large part of the subbasin. The Beaufort Fisheries facility and the Waste Water Treatment Plant in Beaufort are the most significant sources of discharge in the North River subbasin. Both sources discharge into Taylors Creek. (The Wooten Co., 2006)

The majority of the waters surrounding Beaufort are listed as SA waters, the water quality classification for shell harvesting. The Newport River subbasin contains 34,146 acres of estuarine waters classified for shellfish harvest, of which 11,368 are Outstanding Resource Waters (ORW). In the North River subbasin there are 39,176 acres of shellfishing waters and 25, 958 acres of these waters are classified as ORWs in Core Sound. Both rivers experience periods of anoxia, high fecal coliform concentrations, and turbidity levels. The high fecal coliform levels can have negative impacts on shellfish harvesting, causing area closures. The main source of bacterial contamination is nonpoint source pollution, primarily via stormwater runoff. When areas designated for shellfishing fail to meet their designated use under the CWA, they are listed as impaired waters on the Section 303(d) list of the CWA. Portions of the North and Newport Rivers, Wading Creek, Gable Creek, Gibbs Creek, Turner Creek, and Davis Bay were all listed on the 2004 North Carolina 303(d) Impaired Waters List due to the closures in their shellfish harvesting areas. (The Wooten Co., 2006) Some of these closed areas that surround Beaufort are delineated by the cross hatched areas on the NCDENR Shellfish Sanitation map in Figure 5.

Figure 5: Closed Shellfishing Areas Surrounding Beaufort, NC



To deal with the impaired waters surrounding Beaufort, the Town will need to work with other coastal communities surrounding the impaired waters. Devising a watershed restoration management plan that address the need to reduce stormwater runoff, in lieu of the TMDL for impaired waters required by the CWA, is a less costly and time consuming way for coastal communities to restore these waters to their designated uses. The NCCF has already had the methods in their guidebook approved for use as an alternative TMDL by the EPA and used them to establish plans to deal with runoff for a number of locations including the Lockwoods Folly and White Oak Rivers, Bradley and Hewletts Creeks, North River Farm Wetlands Restoration and the Mattamuskeet Drainage District. The Coastal Federation has also worked with the City of Wilmington to help them reduce stormwater runoff. In addition, the NCCF guidebook contains the EPA's nine minimum components a watershed plan must include to be eligible for federal funding to restore impaired water quality, which will help pay for implementation of the measures in the plan. This grant money removes the burden of a substantial amount of the cost from the communities that need to address the issues of impaired waters but most likely do not have the funds to take action.

The process to restore waters to their designated uses cannot be expected to occur overnight. The planning process alone can take at least a couple years but it is an important step for characterizing the current watershed conditions, identifying stakeholders, setting goals, and determining where the most effective locations are to install projects, that will have the largest runoff reductions and protect areas of ecological importance. Setting intermediate steps towards meeting the final volume reduction goal are important, since only so many projects can be accomplished in a set amount of time, depending on the available resources. Trying to reduce runoff back to the levels that existed almost 40 years ago, when the CWA established the designated uses, could reasonably be expected to take a couple decades. As more projects are completed and runoff volumes continue to decrease, improvements in the water quality along the coastal area should be seen. This can be evaluated by looking at the extent of shellfish closures and the number of closures an area experiences from year to year, both of which should show a decrease over time.

Establishing Total and Intermediate Runoff Reduction Goals

Since one of the primary objectives of this project was to illustrate the use of GIS for establishing volume reduction goals the historical limit was set at 2004, the oldest aerial imagery available from Carteret County. Older aerial photos may be available through other sources but were not available online for public use when I conducted my data search. There was a 7% increase in stormwater runoff levels seen over the 9-year period (2004 – 2013) covered in this analysis, which is set as the volume reduction goal. This 7% reduction target is not a substantial decrease and therefore, should be used as an initial volume reduction goal. Further reduction goals can also be calculated based on older aerial photography, if it can be obtained, or by using paper maps of the area to establish more sizable long-term reduction objectives. Intermediate steps to achieve the final goal can be established based on funding availability and current or future capital improvement project plans.

The 7% intermediate goal is a fairly small reduction, so the time frame should not be extended too far into the future. This reduction could fall in the short-term to mid-term project categories. Short-term objectives are achievable within 2 years. Mid-term milestones are to be accomplished within 5 years. Long-term goals are ones that will take 5 or more years to reach. The time frames for achieving intermediate goals, however, should be determined as part of the watershed restoration plan, based on the assessment of the watershed and what measures will prove most effective in restoring water quality. If LID measures for Beaufort are placed in strategic locations, such as focusing on the waterfront areas first, even a 7% reduction could be enough to show some improvements in water quality.

LID Alternatives for Meeting Reduction Goals

There are a number of items to consider when choosing the options for meeting volume reduction goals. Among them are soil type, budget, secondary objectives (reduce flooding, restore wetlands, etc.), and feasibility of projects. LID measures require soils with some drainage capability, so HSG D regions may not be suitable project areas. The majority of the areas with the soil type listed as D in the analysis are actually B/D, so it is not likely to be an issue in Beaufort. Soils are given dual HSGs (A/D, B/D, or C/D) when they can be drained adequate.

For soils that are more poorly drained or in areas with a high water table installing a backyard wetland would be an alternative to a rain garden. Diverting downspouts and installing rain barrels are still viable options for homeowners in these areas (Table 2). There are more LID options for developments and most are suitable for areas with poorly drained soils or high water tables (Table 3). Since the majority of Beaufort is between 8 and 26 feet above sea level and the water table is 6 feet below sea level, the concerns over working with a high water table do not apply (The Wooten Co., 2006). If removing fecal coliform is a high priority, for example, due to the presence of shellfish areas nearby, the tables also indicate the best alternatives to use. The effect on stormwater flow may also be

Table 2: Stormwater BMPs for Homeowners

BMP Type	Fecal Coliform Removal Efficiency[1]	Effect on Stormwater Flow[1]	Ranking	Works with High Water Table?[2]	Works with Poorly Drained Soils?[2]
Backyard raingarden	High	High		N	N
Dry well	High	High		N	N
Backyard wetland	Medium	High		Y	Y
Rainwater harvesting	Low	Medium		Y	Y
Rooftop disconnection	Low	Medium		Y	Y

1 = Based on DWQ Stormwater BMP Manual and best professional judgment
2=Taken from DWQ Stormwater BMP Manual

an important consideration in choosing which measures to implement. For instance, if controlling flooding or preventing the overloading of stormwater drainage systems is important, then choosing options that have a medium or high effect on stormwater flow could be important. About ¾ of the land in Beaufort is susceptible to flooding from Category

1 & 2 hurricanes and all of the area to storm surge from Category 4 &5 hurricanes. In addition, 41% of the Town falls within the 100-year floodplain and 65% in the 500-year floodplain. Subsequently, including secondary goals to reduce flooding could be an important item to include in a watershed restoration plan for the Beaufort area.

Table 3: Stormwater BMPs for Large or Small Scale Development Areas

BMP Type	Fecal Coliform Removal Efficiency[1]	Effect on Stormwater Flow[1]	Ranking	Works with High Water Table?[2]	Works with Poorly Drained Soils?[2]
Bioretention	High	High		N	N
Backyard raingarden	High	High		N	N
Dry well	High	High		N	N
LID techniques	High	High		Y	Y
Backyard wetland	Medium	High		Y	Y
Pond retrofit/naturalization	Medium	High		Y	Y
Stormwater wetland	Medium	High		Y	Y
Wet detention basin	Medium	High		Y	Y
Rainwater harvesting	Low	Medium		Y	Y
Rooftop disconnection	Low	Medium		Y	Y
Level spreaders and filter strips	Medium	Low		Y	Y
Riparian buffer restoration	Medium	Low		Y	Y
Green roofs	Low	Low		Y	Y
Permeable pavement	Low	Low		N	Y

1 = Based on DWQ Stormwater BMP Manual and best professional judgment
2=Taken from DWQ Stormwater BMP Manual

The costs of individual BMPs can vary depending on a number of variables, such as the prices of materials, the size of the installation, and the cost of labor. Homeowners who

Table 4: LID Implementation Costs

BMP Type	Cost per unit
Stormwater runoff reduction	
Bioretention	\$200 per ft^3 cell size
Backyard raingarden	\$3 - \$12 per ft^2
Dry well	\$4 - \$9 per ft^3 of storage volume
LID techniques	n/a
Backyard wetland	\$170 - \$550 depending on surface area
Pond retrofit/naturalization[1]	\$13/yd^3 grading, \$1.20/ft^2 planting, \$3,000 weir
Stormwater wetland[1]	\$13/yd^3 grading, \$1.20/ft^2 planting, \$3,000 weir
Wet detention basin[1]	\$13/yd^3 grading, \$1.20/ft^2 planting, \$3,000 weir
Level spreaders and filter strips	\$5 - \$20 per ft
Riparian buffer restoration	\$400 per acre
Rainwater harvesting	\$200 per rain barrel, \$1000 per 1400-gal cistern, \$10,000 per 10,000-gal cistern
Green roofs	\$9 - \$12 per square foot of roof
Permeable pavement	\$8 - \$12 per square foot of pavement
Downspout disconnection	\$9 per downspout
Source control	
Pet waste education program	\$5,000
Pet waste station	\$320 per station
Livestock manure management education program	\$5,000
Wildlife education program	\$5,000
Boat pumpout station	\$10,000 average, \$60,000 maximum
Boat education	\$5,000
Septic education program	\$5,000
Septic maintenance	\$220 (pumpout), \$3000 (repair) per house
Cooperative Extension Education Outreach staff funding	\$40,000/year

are willing to install their own rain garden, rain barrel, or downspout diverters can save a substantial amount of money. A rain garden, for instance, can cost an average of $3 - $12 per square foot, so installing a 150 ft^2 garden can cost from $450 to $1800 (Table 4). Table 4 gives some cost estimates for common LID types including installation of backyard wetlands or permeable pavement and education programs. The actual costs can vary considerably. A 50-gallon rain barrel, for example, can be purchased for under a $100, and if the owner does the installation there is no addition cost. This is over $100 less than the $200 per rain barrel listed in the table.

Stormwater Runoff Reduction Scenarios for Beaufort

The NCCF guidebook provides a Scenario Accounting Tool, in an excel spreadsheet, to track the amount of runoff reduction that has been achieved as LID projects are completed. It can also be used to assess the most cost effective measures to implement in order to reach the established reduction goals. I ran a number of scenarios using this tool to illustrate what Beaufort could do to achieve a 7% reduction in stormwater runoff, equaling 2,392,010.28 ft^3. The tool takes into account the soil type where the alternatives are implemented, so a separate spreadsheet was completed for each of the four HSGs. For each soil group the total number of parcels was summed. One set of three scenarios was then run with downspout disconnects and 50 gallon rain barrels installed for 50% of the parcels in Beaufort. It also included 6 cisterns, 1000 gallons each. The first scenario installed rain gardens for 25% of the parcels, the second for 50% of the parcels, and the third for 75% of the parcels (Table 5). The other set of three scenarios installed the same amount of rain

Table 5: Runoff Reduction Scenarios Using 50% Downspout Disconnects Target

Scenario Comparisons						
Runoff Reduction Goal = 2,392,010.28 ft^3						
50% of Residential & Commercial Parcels Install Downspout Disconnects *						
Soil Type	25% Parcel**	Cost	50% Parcel **	Cost	75% Parcel **	Cost
A	171,431	$424,880.00	272,751	$696,880.00	374,071	$968,880.00
B	376,606	$1,188,970.00	581,356	$1,888,970.00	784,936	$2,584,970.00
C	313,656	$1,115,950.00	482,716	$1,747,950.00	650,706	$2,375,950.00
D	939,047	$3,499,140.00	1,389,497	$5,215,140.00	1,839,947	$6,931,140.00
Total Reduction	1,800,740		2,726,320		3,649,660	
Total Cost		$6,228,940.00		$9,548,940.00		$12,860,940.00
* Rain Barrels (50 gallons) Installed for 50% of the Parcels in Beaufort & 6 (1000 gallon) Cisterns						
**The # of Rain Gardens Installed Varied for Each Scenario as a % of the Parcels						

barrels but installed downspout disconnects for 75% of the parcels. They also included 8 cisterns, 1000 gallons each. The first of the three scenarios installed rain gardens for 35% of the parcels, the second one for 38%, and the third for 40% of the parcels in Beaufort (Table 6). For a complete list of how many rain gardens, rain barrels, cisterns, and downspouts

Table 6: Runoff Reduction Scenarios Using 75% Downspout Disconnects Target

Scenario Comparisons						
Runoff Reduction Goal = 2,392,010.28 ft^3						
75% of Residential & Commercial Parcels Install Downspout Disconnects *						
Soil Type	35% Parcel **	Costs	38% Parcel **	Costs	40% Parcel **	Costs
A	226,415	$536,792.00	238,335	$568,792.00	245,785	$588,792.00
B	488,736	$1,474,190.00	514,028	$1,562,005.00	529,686	$1,614,190.00
C	401,422	$1,372,660.00	421,752	$1,448,660.00	435,662	$1,500,660.00
D	1,163,152	$4,196,010.00	1,218,802	$4,408,010.00	1,253,452	$4,540,010.00
Total Reduction	2,279,725		2,392,917		2,464,585	
Total Cost		$7,579,652.00		$7,987,467.00		$8,243,652.00
* Rain Barrels (50 gallons) Installed for 50% of the Parcels in Beaufort & 8 (1000 gallon) Cisterns						
**The # of Rain Gardens Installed Varied for Each Scenario as a % of the Parcels						

disconnects were installed for each soil type and the total for each scenario see the table I Appendix D. The scenario that comes the closest to and meets the reduction goal is the scenario with 75% downspout diverters and 38% rain gardens, which reduces runoff by 2,393,057 ft^3. It is also the least expensive alternative that meets the reduction goal, costing $7,987,467.00.

On examination of the estimates provided by the Scenario Accounting Tool I believe these numbers may be higher than the actual installation costs for the proposed reduction projects. When looking at the cost for 136 rain barrels (50 gallons) the estimated cost is valued at $40,800.00, which would be a cost of $300.00 per unit. Pricing these out online most 50 gallon rain barrels cost under $100.00, making the assessed amount in the analysis over three times higher. As an example, using a midrange price for rain barrels of $89 the total for 136 (50 gallon) rain barrels $12,104.00. Although, I did see some rain barrels for sale for $15 on the side of the road on Hwy 101 in Beaufort, which would make the total cost even lower. The downspout disconnection per downspout price also seems high. One example estimated that for 204 downspouts the total would be $6,120.00, a cost per unit of $30.00. This is quite a bit higher than the $9 per downspout estimated on the LID Implementation Cost table (Table 4). At $9 per downspout the total for 204 downspouts would be $1,836.00. Based on these two examples I would expect the actual cost of implementing the various scenarios presented to be much lower. Some adjustments may need to be made to the calculations in the Scenario Accounting Tool before it is useful for providing a more accurate assessment of the total costs for implementing different alternatives.

Over the next 5 years Carteret County has set aside $14,900,000.00 in its Capitol Improvement Project (CIP) budget for environmental protection. Other CIP funds that are used for city maintenance projects may also be allocated to LID projects. In addition, partnering with organizations like the NCCF could also potentially provide more grant money for projects from other sources, in addition to the 319 federal grant funds. Between the CIP funds, grant monies, and community support achieving the initial reduction goal of 7% should be feasible. The City of Portland, OR provides a perfect example of how BMPs for reducing runoff can be incorporated into city projects, regulations, and outreach programs.

A Case Study: Portland, OR

Successful incorporation of LID measures in a city or community requires a multifaceted approach that incorporates both public and private involvement. The city of Portland, OR provides a good example of the kinds of programs that can be developed to reduce stormwater runoff. Portland is bordered by the Columbia and Willamette Rivers. Over half the city is covered by impervious surfaces and the stormwater runoff from these surfaces caused water quality issues in the surrounding waterways. To improve water quality they created a stormwater plan that achieves regulatory compliance, education, outreach, and community greening and beautification. (WERF, 2009)

Portland's stormwater program was initiated in the 1990s to comply with the NPDES MS4 Discharge Permitting regulations. Portland's Bureau of Environmental Services (BES) began developing a stormwater management plan that incorporated new techniques, which they monitored to determine BMP feasibility and effectiveness. The BES identified areas where they were failing to address regulations, and then collaborated with other departments to find new best management practices (BMPs) to meet them. In 1996, the City established the Stormwater Policy Advisory Committee (SPAC), made up of a diverse consortium of stakeholders including the stormwater treatment industry, landscape architects, engineers, institutional organizations, and architects. SPAC came up with the policy and code statements for the city's stormwater management handbook that described the requirements for stormwater management and particular BMP design methodologies. (WERF, 2009)

The resulting stormwater management plan detailed how the City would manage stormwater and specified that LID BMPs to reduce pollutants in runoff would be implemented. The City amended codes governing new and redevelopment to ensure private property owners employed the BMP requirements. They update the manual every two years to incorporate stakeholder feedback and information gained from monitoring their exhibition projects. Recognizing the need for internal organization and promotion of sustainable stormwater management systems, the City formed the Sustainable Infrastructure Committee (SIC) in 2001. They were tasked with coordinating efforts by City staff to explore options, such as stormwater recycling, enhanced street landscaping, and porous pavement, to limit the effects of City projects on water quality. (WERF, 2009)

The Sustainable Stormwater Management Program was established next, within BES, to perform a variety of functions. They became responsible for monitoring and testing the performance and design of pilot stormwater BMPs, providing technical help to developers and designers who are integrating stormwater methods into their sight plans, and partnering with property owners, public agencies, and the federal government on project designs, financing, and execution. In addition, they create supporting policies and execute certain programs, such as Green Streets, ecoroofs, and monitoring. Furthermore, they provide outreach, public education, and documentation on projects. (WERF, 2009)

Portland chose to lead by example in implementing LID measures. The Green Streets project began with pilot projects that retrofitted a number of streets in the city's right-of-way with landscaped curb extensions, swales, planter strips, pervious pavement, and street trees, to retain and infiltrate stormwater. Stormwater managers and planners consulted with homeowners about their aesthetic preferences and expectations, to gain public support. Because of the attractiveness of these installations, residents now value them as an amenity. As part of the Green Streets project, the City adopted a policy directing City agencies to include green building practices in all the city's buildings. This policy requires all new City-owned facilities and roof replacement projects to use ecoroof designs. (WERF, 2009)

Portland also uses incentive programs to reduce runoff from residential or commercial sources. The Downspout Disconnection Program was created in 1993 to provide outreach and incentives for residents in certain neighborhoods to divert rainwater from roofs into gardens and lawns. The program succeeded in disconnecting 56,000 downspouts between 1993 and 2011, removing 1.3 billion gallons of stormwater annually from the combined sewer system. (POES, 2013)

The City Council established Clean Rivers Rewards, in 2000, to offer residential stormwater utility fee ratepayers a discount of up to 30% for keeping stormwater from running off their property. It also provides commercial customers a discount for controlling runoff from impervious surfaces. Credits are offered for having an impervious footprint under 1,000 sq. ft., implementing LID measures, and retaining or creating tree cover. To assist ratepayers with retrofits, BES provides a technical assistance webpage and holds workshops for residential and commercial customers. Since October 2006, over 35,000 property owners have signed up for this program. (WERF, 2009)

Incentives also exist for developers. The City offers floor area bonuses for developers proposing buildings in Portland's Central City Plan District if they install an ecoroof. These ecoroofs are vegetated roof systems that decrease runoff and provide air quality, habitat, aesthetic, and energy saving benefits. (WERF, 2009)

In addition to the LID projects implemented in new development, redevelopment, and capitol improvement projects around the City, Portland schools partnered with the City to install LID measures that manage up to 90% of the stormwater runoff on site. These projects are used as a learning opportunity to teach children about watershed health and how using LID BMPs help prevent sewer backups in neighboring houses. (WERF, 2009)

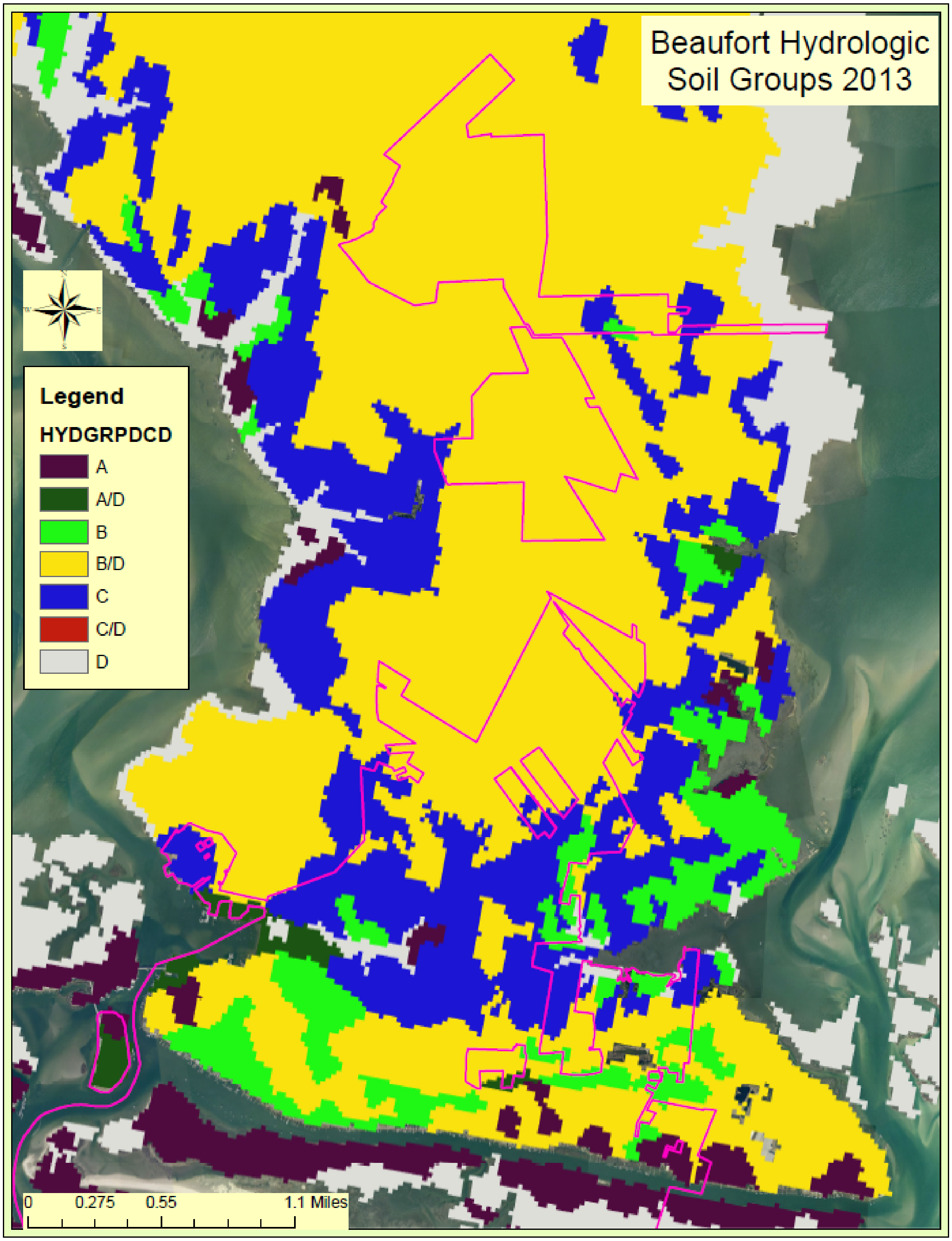
Conclusion

The success of Portland's stormwater management plan demonstrates that LID is a viable solution for improving water quality through preventing runoff. In addition, the approval of several of the NCCF's projects by the EPA to use the methods in the NCCF guidebook as an alternative TMDL, that is eligible for federal funding, makes runoff reduction an attractive option for addressing the impaired water quality around Beaufort. Setting the volume reduction goals using GIS and the Runoff Calculation Tool is a fairly simple process, as illustrated by my analysis, and with some improvements the Scenario Accounting Tool could be more useful in assessing which alternatives to implement in order to meet the established reduction goals. At the present time the scenario tool appears to be estimating costs that are 2 or 3 times higher than they would be in reality. If the 7% reduction scenario that used installations of rain gardens for 38% of the parcels was even half the estimated price, at $3,993,733.50, it starts to sound like a more reasonable alternative.

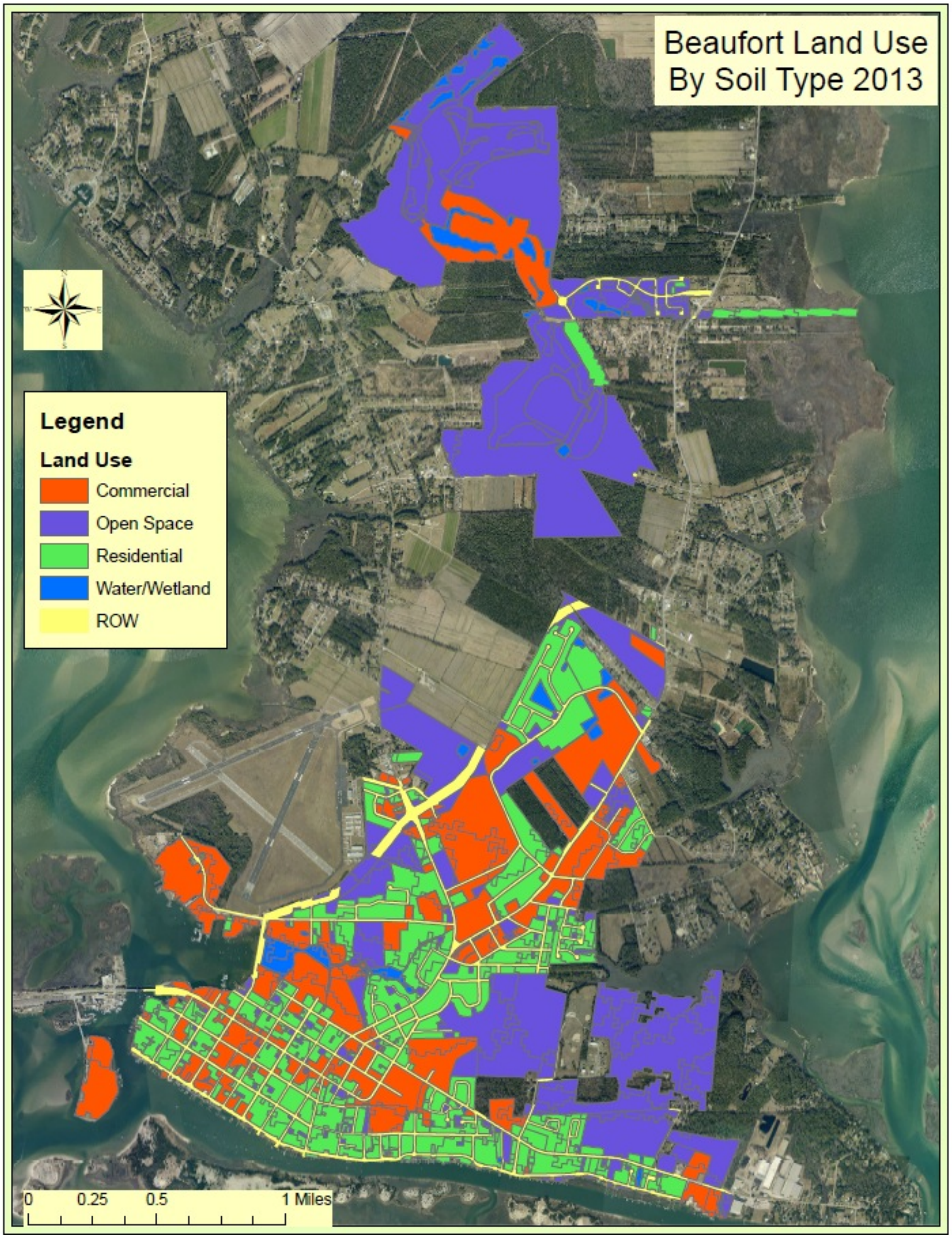
The cost to implement all the reduction projects would not fall entirely on the city. The total cost of reducing stormwater runoff can be distributed between federal resources, city funding, and the residents of Beaufort. If Beaufort even had to come up with a third of the funds for the projects, equal to $1,331,244.50, it doesn't sound to bad compared with the millions of dollars required for upgrading traditional stormwater and sewer infrastructure and LID has the added benefit of improving water quality. In effect, it provides two benefits for one price tag, removing impairments from surrounding waters and reducing maintenance costs for stormwater infrastructure. Portland reported saving $58 million on their stormwater system due to the reductions in stormwater runoff provided by their LID installations. Their green streets projects totaled $86 million, compared to the estimated $144 million that would have been required for conventional infrastructure, and provide the added benefits of reduced flooding, cleaner waterways, and a healthier watershed (NRDC).

Incentive plans can be developed in Beaufort, similar to the ones used in Portland, that help people who are interested in installing rain gardens, disconnecting downspouts, installing rain barrels, and any other LID projects. Giving residents credits on their sewer bill, for example, would be one possible way to incentivize people to implement low impact development retrofits. The amount of credits could be dependent on the volume of runoff reduction achieved. Beaufort can include installation of rain gardens on city properties and along ROWs, to catch runoff from streets, sidewalks, and parking lots, as part of their capital improvement projects. The Town can use these installation locations as models to show residents the improved appearance of neighborhoods and the other benefits that LID projects provide. Further steps could be taken to included public outreach campaigns that teach city residents about stormwater runoff issues or education them about the importance of cleaning up after pets. LID building standards for future development and retrofits for current structures should also be incorporated into the building requirements for the Town. Larger projects geared towards achieving greater reduction goals over the long run can also be integrated into capital improvement projects, such as refinishing parking lots with permeable pavement. Taking these steps can improve water quality and protect it over the long run.

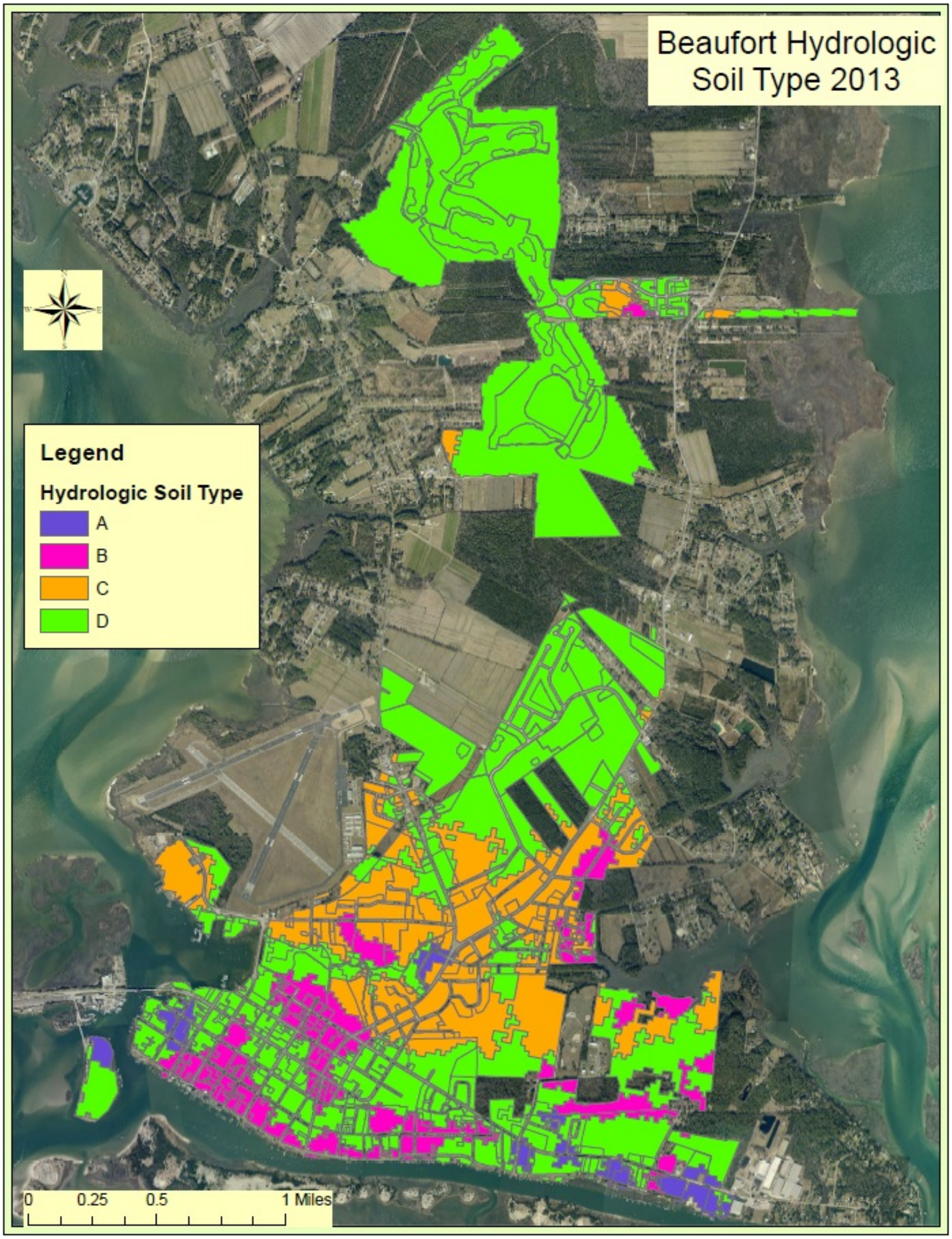
Appendix A – Map of Beaufort Hydrologic Soil Groups



Appendix B – Map of Beaufort Land Use By Soil Type



Appendix C – Map of Beaufort Soil Types



Appendix D – Total Number of LID Installations for Each Scenario

Scenario Accounting Tool Input Parameters					
Scenario	Soil Type	Rain Gardens	Rain Barrels	Cisterns	Downspout Disconnects
1	A	95	136		136
	B	268	349	6	349
	C	253	315		315
	D	804	858		858
	Total	**1420**	**1658**	**6**	**1658**
2	A	163	136		136
	B	443	349	6	349
	C	411	315		315
	D	1233	858		858
	Total	**2250**	**1658**	**6**	**1658**
3	A	231	136		136
	B	617	349	6	349
	C	568	315		315
	D	1662	858		858
	Total	**3078**	**1658**	**6**	**1658**
4	A	122	136	2	204
	B	338	349	6	523
	C	316	315		472
	D	975	858		1287
	Total	**1751**	**1658**	**8**	**2486**
5	A	130	136	2	204
	B	359	349	6	523
	C	335	315		472
	D	1028	858		1287
	Total	**1852**	**1658**	**8**	**2486**
6	A	135	136	2	204
	B	373	349	6	523
	C	348	315		472
	D	1061	858		1287
	Total	**1917**	**1658**	**8**	**2486**

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